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Shipbuilding Productivity Rates of Change in East Asia

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Overseas shipyards routinely deliver oceangoing merchant vessels at prices that are a fraction of what the best-performing U.S. shipbuilders are able to quote. Despite efforts to attain commercial competitiveness, it is not clear that the performance gap between the U.S. industry and international shipbuilders is closing. In fact, at least in the case of the U.S. industry compared with the global industry leaders (Japan and South Korea), it is possible that the productivity gap may be widening as a result of the process of relentless performance improvement that has been under way for years in those two nations. In this working paper, we provide a quantitative indication of the rates of change in productivity in Japanese and South Korean shipyards during recent decades. Accompanying this are some comments on the environment that has produced these productivity improvement rates. With this paper, we hope to contribute to an understanding of the dynamics of international competition in the merchant shipbuilding industry.

Introduction

UNITED STATES–BASED shipbuilders are engaged in efforts to develop advanced technologies and to realize process improvements with the goal of reducing the cost of warships to the U.S. Navy and establishing U.S. international shipbuilding competitiveness. The industry's consensus vision, per the National Shipbuilding Research Program's (NSRP) *Strategic Investment Plan* (*Revision 2,* 2001, p. xi) is to evolve U.S. shipbuilding into a robust, self-sufficient industry that, among other things, "Is recognized as able to build ships as efficiently and cost effectively as world competitive shipyards, and has captured a significantly increased share of commercial markets."

Recent productivity improvements in U.S. shipbuilding have been reported (NSRP 2001, p. xiii). However, productivity improvements have also been realized in shipyards in the countries that are already the world market leaders. The result is that the cost to build a merchant ship in the United States continues to be uncompetitive by a wide margin, and it is not clear if the gap is narrowing.

Documented comparisons of U.S. shipbuilding costs versus costs in competitive overseas shipyards are seldom published. However, there has been an exception recently. Earlier this year Kvaerner reported some cost information for its first Philadelphia-built containership, currently being erected (Holcomb 2002). These data are shown in Table 1.

Here, the international comparison is straightforward, because the basic design of the ship was sourced (with some modifications) from Kvaerner Warnow Werft in Germany (Matz 2001). For this case, the ratio of the U.S. cost to the cost in a competitive European shipyard is estimated by Kvaerner at 1:4.5. Other shipbuilders have considered their costs, checked international market prices, and find the difference large enough to be difficult to explain.

Consequently, the authors were asked to consider why the difference in U.S. and competitive overseas cost performance in merchant shipbuilding is so great, and to offer some comments, hopefully of an explanatory nature. In this paper, we present some applicable data from the literature and we offer some comments for the purpose of contributing to a constructive discussion.

Global leaders in productivity

Today, Japan and South Korea are approximately tied for first place in global merchant shipbuilding market leadership. China ranks next. Table 2 shows the breakdown of ships delivered by these three nations by gross tons for the last 2 years.

How productive are these three nations, and how do they compare with Europe? In terms of overall shipbuilding competitiveness, we can start with three key factors: productivity, labor cost, and delivery time. Using some information from Nagatsuka (2002), we can put together Table 3.

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Table 1 Kvaerner containership costs: U.S. hull no. 1 versus Europe

Contract price, U.S.	$110 million
Estimated cost, U.S.	$150 million
Estimated cost of almost identical ship at a Kvaerner yard in Europe	$33 million

Data from Holcomb 2002.

Table 2 Shipbuilding deliveries, percent of world market by gross tons

Year	2001 (%)	2000 (%)
Japan	38.4	38.2
South Korea	37.1	38.9
China	5.8	4.7

Calculated from Lloyd's World Fleet Statistics as at 31 December 2000 and 31 December 2001.

Table 3 Some general competitiveness factors

	Japan	S. Korea	China	W. Europe
Productivity	1.0	0.7	0.2	0.6
Labor cost	1.0	0.5	0.2	0.8–1.2
Delivery time:				
Japan: shortest delivery time				
S. Korea: longer than Japan				
China: much longer than Japan				
Europe: slightly longer than Japan				

Baseline performance level is Japan at 1.0.
Data from Nagatsuka 2002.

From this information, the global productivity leader is Japan and the cost leader is Korea. Japan has an advantage in delivery time. If we use a double-hull very large crude carrier (VLCC) as an example, and we look at production hours and duration from start of construction to delivery, then a Japanese yard might typically take 400,000 to 600,000 hours and around 6 to 8 months. In South Korea, we are likely to see 500,000 to 700,000 hours and 7 to 11 months for the same work (Nagatsuka 2002). The Korean performance deficit is approximately offset by the lower labor cost.

We have very briefly sketched a general "snapshot" of the existing situation in international merchant shipbuilding productivity. More information of this kind can be found in the literature. However, shipbuilding productivity cannot be understood via this type of static view because, in the case of the shipbuilding leaders, productivity is rapidly evolving. Evolution in shipbuilding productivity in Japan and South Korea (and probably in certain nations in western Europe) probably explains why it is proving so difficult for the U.S. industry to close the productivity gap.

Productivity trends in Japan and South Korea

Japan and South Korea are currently running almost neck-and-neck in the contest for first place in world merchant shipbuilding. Japan has been a major shipbuilder for over 100 years and became the world's largest shipbuilding nation in 1956 (Chida & Davies 1990, p. 106). The Korean industry, however, dates back only to the early 1970s. Recall that a disastrous global shipbuilding crash occurred in the mid 1970s. The Korean industry therefore came on line at a particularly inauspicious juncture and has had to struggle to survive from day one (see, for example, Amsden 1989, pp. 269–290).

This also meant that just as the Japanese shipbuilders were working to come to grips with the effects of the market crash, they had a new and aggressive competitor to watch out for. The appearance of the Korean industry, with its modern, state-of-the-art facilities, economies of scale, and lower labor costs, put considerable pressure on the Japanese industry, which, in an environment of slowed product innovation, has been compelled to compete on price. The Japanese have had to carry out intense productivity improvement efforts in order to stay competitive.

One result of this intense competition within East Asian shipbuilding has been steady improvements in productivity. Analysts at the Japan Maritime Research Institute (JAMRI; and elsewhere) have been studying and documenting this. Using some of JAMRI's data, let us first look at South Korea.

Figure 1 shows time series plots of gross tons and compensated gross tons (CGT) per person in the Korean industry. The Korean shipyards are owned by diversified industrial conglomerates, so "person" here means people in the shipbuilding department (officers, engineers, workers, including in-yard subcontractors) and the land machine manufacturing department (whose labor is difficult to separate out).

The JAMRI data indicate that after an initial start-up period in the 1970s, the Korean yards have been steadily and significantly increasing productivity during the past 20 years. From 1990 to 1998, CGT per person almost doubled, which represents a compounded annual gain of over 8%.

Now let us look at some similar data on Japan. Figure 2 shows shipbuilding output in terms of gross tons completed, and also per person in terms of gross tons and CGT. "Person" here includes all people working in the shipyard: officers, engineers, and workers, including in-yard subcontractors and so forth.

The picture here is quite similar to South Korea, which is unsurprising, because the Japanese and the Koreans are more or less equal competitors in an overall sense. From 1980 to 1998, Japanese productivity in terms of CGT per person rose by about 7% compounded annually. For the period 1990 to 1998, the annual rate is just under 9%.

This productivity increase was accompanied by a parallel increase in output, as shown in the dotted curve of Fig. 2. During this period (1988 to 1998), shipbuilding employment in Japan followed a basically flat trend, as shown in Fig. 3.

In Fig. 3, for "whole Japan" and "main yards," the number of employees is the total head count in the shipyards, including officers, engineers, workers, in-yard subcontractors, and so forth. For "7 majors," the number of employees is the number of people in the shipbuilding division (newbuilding and repair), including in-yard subcontractors.

The number of employees in the new building departments of the Japanese shipbuilding companies peaked at 256,300 in 1975, declining to 83,300 by 1988. As of 1998, the total new building department employment at all of the seven major Japanese shipbuilders totaled to about 19,850 (Nagatsuka 2000, pp. 4–5), and

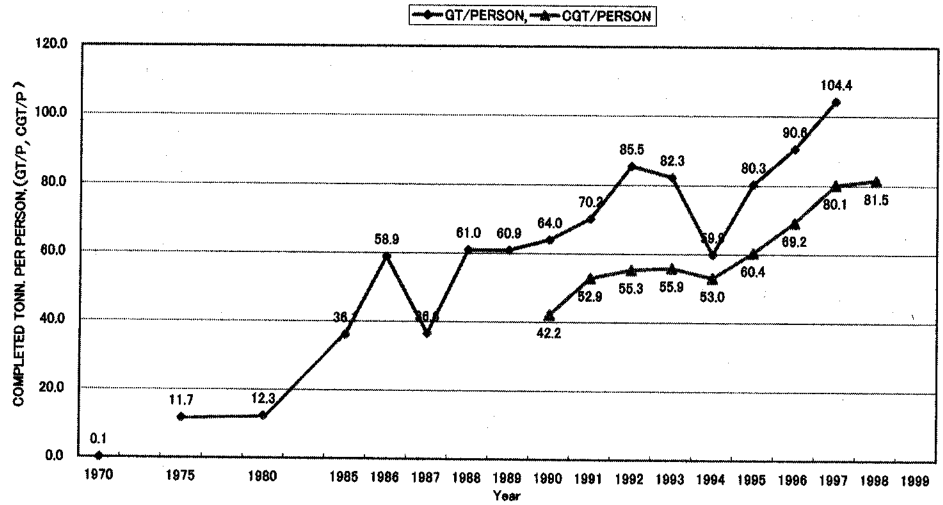

Fig. 1 Shipbuilding output per person, South Korea. CGT = compensated gross tons; GT = gross tons. (Reprinted from Nagatsuka 2000.)

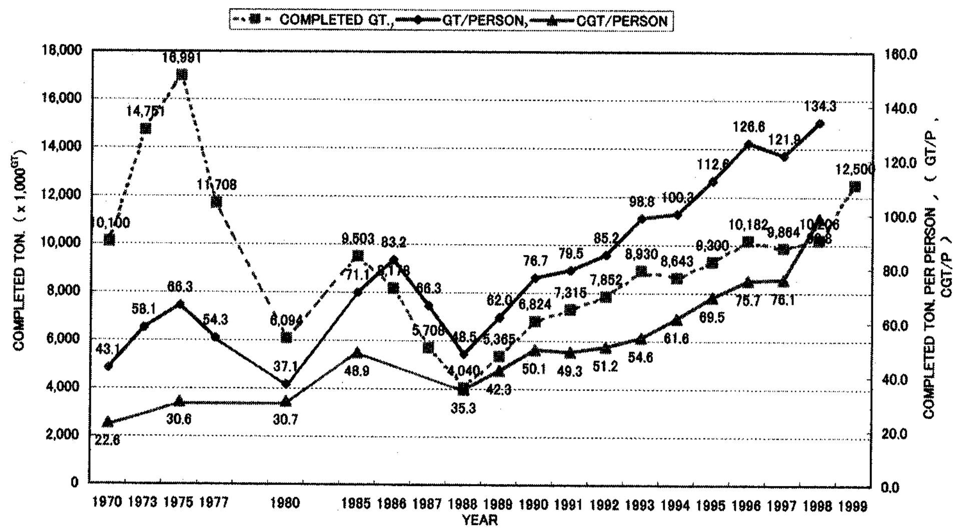

Fig. 2 Shipbuilding output and output per person, Japan. CGT = compensated gross tons; GT = gross tons. (Reprinted from Nagatsuka 2000.)

this probably is about the same today. By comparison, employment at Northrop Grumman Ship Systems is 17,000, and there are 18,500 employed at Northrop Grumman Newport News (Northrop Grumman Corporation 2001).

As a final look, if we consider productivity in Japanese main yards on the basis of gross tons per labor hour, we get the picture shown in Fig. 4. Here, "labor hour" includes hours expended by all people working in the shipyard, including officers, engineers, and workers (including in-yard subcontractors, etc.). The data show that productivity in Japanese main yards as measured in this manner increased by a factor of 6.5 from 1965 to 1997. This represents a productivity improvement rate of approximately 6% compounded annually over 32 years. This is consistent with the other data.

In our judgment, the information shown in Figs. 1 through 4 is credible. These productivity improvement rates provide useful business performance benchmarks.

Some themes in Japanese shipbuilding productivity improvement

In the previous section, the productivity improvement rates that the Japanese and South Korean shipbuilding industries have been sustaining over recent decades have been described. How are these productivity improvement rates being achieved? This question has been approached in many ways in the literature. Still, we believe it is worthwhile to review some of the principal themes that have enabled the realization of the productivity rates of change described above. For now, we will consider just the Japanese case.

In Japanese shipbuilding, the single most important management imperative is cost reduction. All other considerations take second place or lower compared with this vital business survival need. Opportunities to reduce cost are identified and exploited via any means possible. This includes what Americans might call "lean production," as well as tools and techniques that originated

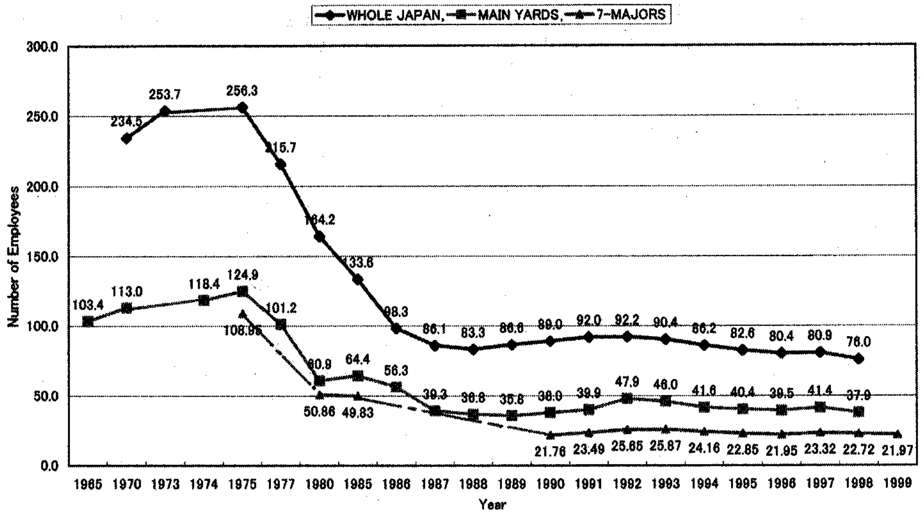

Fig. 3 Shipbuilding employment, Japan. (Reprinted from Nagatsuka 2000.)

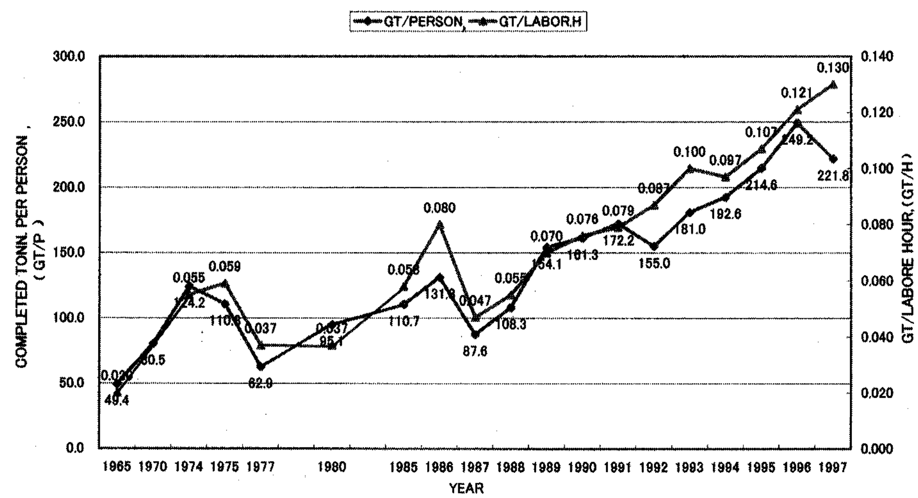

Fig. 4 Productivity in Japanese main yards. CGT = compensated gross tons; GT = gross tons. (Reprinted from Nagatsuka 2000.)

in Taylorist scientific management and Henry Ford's drive to automate. For a discussion of how these process improvement concepts relate to Japanese shipbuilding, see Koenig et al (2002b).

For the rest of this section, some of the more important cost-reduction actions and themes that are being applied in Japanese shipbuilding are listed along with a few comments. In some instances, discussions of specific technologies or themes have been provided in one of our *Shipbuilding and Ocean Technology, Asia-Pacific Region* newsletters (Narita & Koenig, various dates).

Reduction in the number of workers

This is a longstanding, primary, "overarching" management goal. Many of the rest of the cost reduction themes in this section are directed ultimately toward the goal of cutting payroll. Getting people "out of the loop" is one of the most fundamental means of improving productivity. As mentioned above, employment in the Japanese shipbuilding industry is way down from its peak in the mid 1970s. U.S. visitors are often struck by the "emptiness" of Japanese shipyards. A typical Japanese shipyard delivering around a dozen or so large merchant vessels per year will have a total of around 1,900 people working on the site of the yard, of which only half are company employees.

In addition to the general need to reduce staffing, concern exists because the workforce in Japanese shipbuilding is aging and it is becoming more difficult to recruit young people. This applies to naval architects and engineers as well as production workers.

Schedule compliance and schedule-driven process improvement

A key reason for Japanese shipbuilding productivity is that schedules are rigorously formulated and not allowed to slip. Production management is driven by schedule compliance based on ensuring that milestones are met. In cases where problems occur, special action is taken to get the work back on track as quickly as possible without affecting other operations. Line stoppage to correct process problems (a key feature of the Toyota production system) is not allowed. See Koenig et al (2002b) for more on this.

Activity network modeling is not used to develop shop schedules. Shop schedules are built using basic approaches and tools, such as Gantt charts. For each task on the Gantt chart, the schedule target is defined by making a strategized, incremental reduction in the time required previously. Because Japanese shipyards build many ships per year, it does not take a long time for these improvements to accumulate. This process is one of the basic mechanisms through which Japanese shipyards realize constant improvements in productivity over the years.

Faster design-build time

In a capital-intensive heavy industry such as shipbuilding, cost effectiveness depends on capacity utilization. This means that throughput must be maximized. In this respect, the benefits of series production are well understood and in most yards are exploited to the fullest extent. Many other technical and managerial innovations contribute to this.

Improved accuracy control

This is a critical concern. Japanese shipbuilders' attention to accuracy control has been legendary for years, and the focus has been sharpening recently. High precision causes a technological trickle-down effect. It reduces or eliminates rework, lowers the required skill content in shop floor jobs (see, for example, Okumoto 2000), makes it possible to employ more robots, enables collarless construction, and so forth. Collarless construction, although not universal, has been introduced in several Asian shipyards in recent years; see Koenig et al 2002b and Newsletter No. 10 (Narita & Koenig) for more on this. See also Newsletter No. 6 for a discussion of a recent Japanese multicompany research effort in the area of accuracy control.

More use of automation

This takes various forms, such as welding robots, painting robots, and so forth. In addition to robotics, Japanese shipyards make extensive use of other forms of automation, such as small, handy automatic welding machines. An impressive new example of automation is the new automatic line heating workstation at IHI's Kure Shipyard. This system, devised to cope with the decreasing availability of skilled labor, reduces the number of workers, speeds up the process, and increases throughput (Koenig et al 2002a).

Computer-integrated manufacturing

See Newsletter Nos. 8 and 10 (Narita & Koenig). Japanese shipyards have been working both in-house and collaboratively to develop computer systems to streamline and integrate sales, design, production planning, process planning, procurement, and so forth. Somewhat different approaches have been followed by the "seven majors" and the medium-sized sector in information technology development, but all recognize the value of working on this.

Operations management

Although lately there has been a lot of focus on technology development for increased productivity, the well-known principles of Japanese operations management, such as continuous improvement, worker involvement, and so on, remain in force. These elements continue to contribute to cost reduction in the Japanese industry.

Other factors

- Standardization, unitization, and so forth
- Feedback systems, to fully capture and utilize past experience
- Input of the production strategy at early stages of ship design
- Minimization of staging (scaffolding)
- Fewer parts. If ships are built using fewer parts, they are quicker and easier to design and produce. For example, Japan's newest shipyard, the Imabari facility at Saijo, can handle steel plates 30 m long and 5.5 m wide and can lift 1,500-ton blocks (Ohno 2000). The result is fewer plates; fewer blocks; fewer things to order, manage, and process; less weld line; fewer lifts to schedule; and so on.
- Laser steel processing. See Newsletter No. 7 (Narita & Koenig) and various reports on Bender Shipbuilding's investment in Japanese laser cutting technology. These explain the rationale behind this technology, which is widely used in Japanese shipyards, including many medium-sized and even small yards.
- Intercompany alliances. Some Japanese shipbuilding companies have built alliances to share ship designs (to reduce design cost) and make combined purchases (to realize economies of scale). Broader alliances have recently been announced, and we plan to report on their effects at a later date.

Reduced material costs

In the past, among the "seven majors," certain materials tended to be procured within the company group. This habit is dying out. Steel and other main material items are now procured on competitive world markets. Some shipbuilders have been collaborating on material purchasing to gain market power. The need for this may seem surprising, considering the volume of materials Asian shipyards go through. (For example, a typical medium-sized Japanese shipyard processes 10,000 tons of steel per month.)

This theme, the reduction of material costs, is a critical objective in the Japanese shipbuilding industry, and we plan to discuss this further in the future.

Discussion

In this paper, we have presented a quantitative indication of productivity improvement accomplishments and trends in the world's leading shipbuilding region: East Asia. There, rapid and sustained productivity improvement is not a strategic option; it is a prerequisite to survival in a brutally competitive commercial environment. With the rise of a more robust Chinese industry, the competition is likely to intensify in the future.

Four years ago, the Maritech Advanced Shipbuilding Enterprise Strategic Investment Plan (1 June 1998 draft) published a comparative breakdown of costs in shipbuilding. This indicated that not only was the U.S. cost structure uncompetitive, but also the cost of materials alone in the United States was around 33% higher than the total cost of the ship in a competitive overseas yard (Fig.

5). See Koenig 2002 for a more detailed analysis of ship production costs in international merchant shipbuilding.

Since that date, U.S. shipyards have reported absolute progress in productivity. However, whether or not they are making headway in becoming internationally competitive depends on their relative progress compared with the global industry leaders. Shipyards in the world's two market leaders (Japan and South Korea) have made (and continue to make) significant, steady gains in productivity. We have found no evidence that the rate of productivity improvement in those countries is slackening. Is the level of effort in the United States sufficient to make international competitiveness a realistic goal?

International merchant shipbuilding is a mature heavy industry operating in an environment of global overcapacity and perceived industry attractiveness on the part of newly industrializing nations. For the existing leaders, there are opportunities to maintain competitiveness, as described previously in this paper, combined with difficulties in exiting the industry due to high sunk costs, local social implications, and other factors.

In this environment, cost reduction is the critical business driver. Cost reduction is aggressively pursued, and there is a firmly established trend in cost reduction achievement on the part of today's leaders. New entry to the industry on the part of a high-cost country will be a challenge.

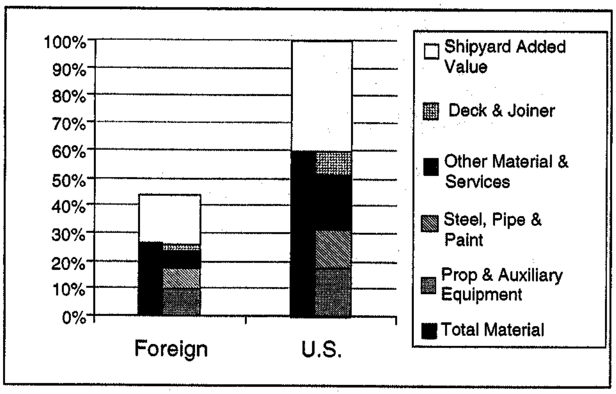

Fig. 5 Shipbuilding costs, foreign and U.S. (Reprinted from Maritech 1998.)

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